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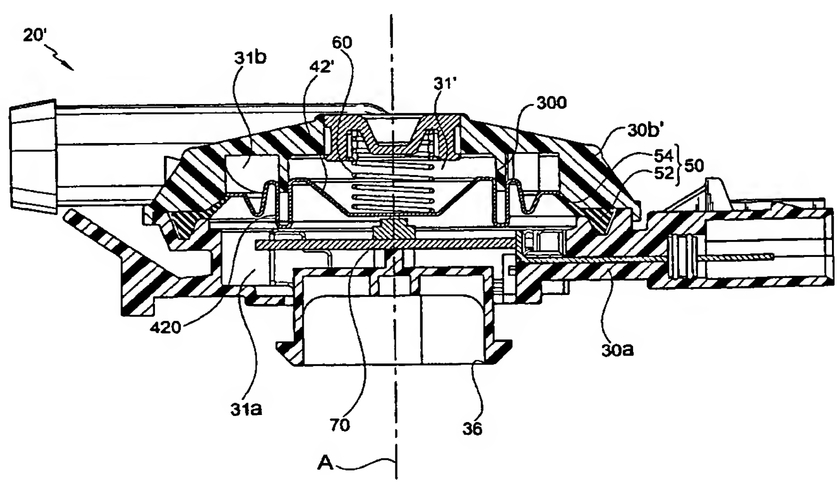

(57) Abstract: An apparatus and method of operating a fuel vapor pressure management apparatus (20) that includes a housing (30) and a pressure operable device (40). The housing defines an interior chamber (31) and includes first (36) and second ports (38) that communicate with the interior chamber. The pressure operable device separates the interior chamber into a first portion in fluid communication with the first port and a second portion in fluid communication with a second port. The pressure operable device includes a poppet (42) movable along an axis and a seal adapted to cooperatively engage the poppet. A first arrangement of the pressure operable device occurs when there is a first negative pressure level at the first port relative to the second port, and the seal is in a first deformed configuration. A second arrangement of the pressure operable device permits a first fluid flow from the second port to the first port when the seal is in a second deformed configuration. And a third arrangement of the pressure operable device permits a second fluid flow from the first port to the second port when the seal is in an undeformed configuration.

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APPARATUS AND METHOD FOR FUEL VAPOR PRESSURE MANAGEMENT

Cross Reference to Related Applications

[0001] This application claims the benefit of the earlier filing date of U.S. Provisional Application No. 60/298,255, filed 14 June 2001, U.S. Provisional Application No. 60/310,750, filed 8 August 2001, and the U.S. Provisional Application identified as Attorney Docket No. 051481-5093-PR, filed 30 May 2002, all of which are incorporated by reference herein in their entirety.

Field of the Invention

[0002] A fuel vapor pressure management apparatus and method that manages pressure and detects leaks in a fuel system. In particular, a fuel vapor pressure management apparatus and method that vents positive pressure, vents excess negative pressure, and uses evaporative natural vacuum to perform a leak diagnostic.

Background of the Invention

[0003] Conventional fuel systems for vehicles with internal combustion engines can include a canister that accumulates fuel vapor from a headspace of a fuel tank. If there is a leak in the fuel tank, the canister, or any other component of the fuel system, fuel vapor could escape through the leak and be released into the atmosphere instead of being accumulated in the canister. Various government regulatory agencies, e.g., the U.S. Environmental Protection Agency and the Air Resources Board of the California Environmental Protection Agency, have promulgated standards related to limiting fuel vapor releases into the atmosphere. Thus, it is believed that there is a need to avoid releasing fuel vapors into the atmosphere, and to provide an apparatus and a method for performing a leak diagnostic, so as to comply with these standards.

[0004] In such conventional fuel systems, excess fuel vapor can accumulate immediately after engine shutdown, thereby creating a positive pressure in the fuel vapor pressure management system. Excess negative pressure in closed fuel systems can occur under some operating and atmospheric conditions, thereby causing stress on components of these fuel systems. Thus, it is believed that there is a need to vent, or "blow-off," the positive pressure, and to vent, or "relieve," the excess negative pressure. Similarly, it is also believed to be

desirable to relieve excess positive pressure that can occur during tank refueling. Thus, it is believed that there is a need to allow air, but not fuel vapor, to exit the tank at high flow rates during tank refueling. This is commonly referred to as onboard refueling vapor recovery (ORVR).

Summary of the Invention

[0005] The present invention provides a fuel vapor pressure management apparatus that includes a housing and a pressure operable device. The housing defines an interior chamber and includes first and second ports that communicate with the interior chamber. The pressure operable device separates the interior chamber into a first portion in fluid communication with the first port and a second portion in fluid communication with a second port. The pressure operable device includes a poppet that is movable along an axis, and a seal that is adapted to cooperatively engage the poppet. A first arrangement of the pressure operable device occurs when there is a first negative pressure level at the first port relative to the second port, and the seal is in a first deformed configuration. A second arrangement of the pressure operable device permits a first fluid flow from the second port to the first port when the seal is in a second deformed configuration. And a third arrangement of the pressure operable device permits a second fluid flow from the first port to the second port when the seal is in an undeformed configuration.

[0006] The present invention also provides a fuel vapor pressure management apparatus that includes a housing that defines an interior chamber, and a pressure operable device that occupies a first space in the interior chamber. The housing and the interior chamber occupy a volume less than 240 cubic centimeters. The pressure operable device performs a leak diagnostic based on a negative pressure at a first pressure level, relieves negative pressure below the first pressure level, and blows-off positive pressure above a second pressure level.

[0007] The present invention further provides a method of method of managing fuel vapor pressure in a fuel system. The method includes locating between first and second ports a poppet and a seal cooperating with the poppet. The poppet is movable along an axis. The seal is flexible between an undeformed configuration when the seal is disengaged from the poppet, a substantially symmetrically deformed configuration when the seal is engaged with the poppet, and a generally asymmetrically deformed configuration when the seal is engaged

with the poppet. The method also includes positioning the seal in the substantially symmetrically deformed configuration so as to sense a negative pressure at a first pressure level, positioning the seal in the generally asymmetrically deformed configuration so as to vent negative pressure below the first pressure level, and positioning the seal in the undeformed configuration so as to vent positive pressure above a second pressure level.

Brief Description of the Drawings

[0008] The accompanying drawings, which are incorporated herein and constitute part of this specification, illustrate presently preferred embodiments of the invention, and, together with the general description given above and the detailed description given below, serve to explain features of the invention.

[0009] Figure 1 is a schematic illustration of a fuel system, in accordance with the detailed description of the preferred embodiment, which includes a fuel vapor pressure management apparatus.

[0010] Figure 2A is a first cross sectional view of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0011] Figure 2B are detail views of a seal for the fuel vapor pressure management apparatus shown in Figure 2A.

[0012] Figure 2C is a second cross sectional view of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0013] Figure 3A is a schematic illustration of a leak detection arrangement of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0014] Figure 3B is a schematic illustration of a vacuum relief arrangement of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0015] Figure 3C is a schematic illustration of a pressure blow-off arrangement of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0016] Figure 4A is a graph illustrating the operating characteristics of the fuel vapor pressure management apparatus illustrated in Figure 1.

[0017] Figure 4B is a graph illustrating a detail of the operating characteristics of the fuel vapor pressure management illustrated in Figure 4A.

[0018] Figure 4C is a graph illustrating a comparison of the operating characteristics of the fuel vapor pressure management illustrated in Figure 1 with the operating characteristics of a known leak detection device.

Detailed Description of the Preferred Embodiment

[0019] As it is used in this description, "atmosphere" generally refers to the gaseous envelope surrounding the Earth, and "atmospheric" generally refers to a characteristic of this envelope.

[0020] As it is used in this description, "pressure" is measured relative to the ambient atmospheric pressure. Thus, positive pressure refers to pressure greater than the ambient atmospheric pressure and negative pressure, or "vacuum," refers to pressure less than the ambient atmospheric pressure.

[0021] Also, as it is used in this description, "headspace" refers to the variable volume within an enclosure, e.g. a fuel tank, that is above the surface of the liquid, e.g., fuel, in the enclosure. In the case of a fuel tank for volatile fuels, e.g., gasoline, vapors from the volatile fuel may be present in the headspace of the fuel tank.

[0022] Referring to Figure 1, a fuel system 10, e.g., for an engine (not shown), includes a fuel tank 12, a vacuum source 14 such as an intake manifold of the engine, a purge valve 16, a charcoal canister 18, and a fuel vapor pressure management apparatus 20.

[0023] The fuel vapor pressure management apparatus 20 performs a plurality of functions including signaling 22 that a first predetermined pressure (vacuum) level exists, "vacuum relief" or relieving negative pressure 24 at a value below the first predetermined pressure level, and "pressure blow-off" or relieving positive pressure 26 above a second pressure level.

[0024] Other functions are also possible. For example, the fuel vapor pressure management apparatus 20 can be used as a vacuum regulator, and in connection with the operation of the purge valve 16 and an algorithm, can perform large leak detection on the fuel system 10. Such large leak detection could be used to evaluate situations such as when a refueling cap 12a is not replaced on the fuel tank 12.

[0025] It is understood that volatile liquid fuels, e.g., gasoline, can evaporate under certain conditions, e.g., rising ambient temperature, thereby generating fuel vapor. In the

course of cooling that is experienced by the fuel system 10, e.g., after the engine is turned off, a vacuum is naturally created by cooling the fuel vapor and air, such as in the headspace of the fuel tank 12 and in the charcoal canister 18. According to the present description, the existence of a vacuum at the first predetermined pressure level indicates that the integrity of the fuel system 10 is satisfactory. Thus, signaling 22 is used to indicate the integrity of the fuel system 10, i.e., that there are no appreciable leaks. Subsequently, the vacuum relief 24 at a pressure level below the first predetermined pressure level can protect the fuel tank 12, e.g., can prevent structural distortion as a result of stress caused by vacuum in the fuel system 10.

[0026] After the engine is turned off, the pressure blow-off 26 allows excess pressure due to fuel evaporation to be vented, and thereby expedite the occurrence of vacuum generation that subsequently occurs during cooling. The pressure blow-off 26 allows air within the fuel system 10 to be released while fuel vapor is retained. Similarly, in the course of refueling the fuel tank 12, the pressure blow-off 26 allows air to exit the fuel tank 12 at a high rate of flow.

[0027] At least two advantages are achieved in accordance with a system including the fuel vapor pressure management apparatus 20. First, a leak detection diagnostic can be performed on fuel tanks of all sizes. This advantage is significant in that previous systems for detecting leaks were not effective with known large volume fuel tanks, e.g., 100 gallons or more. Second, the fuel vapor pressure management apparatus 20 is compatible with a number of different types of the purge valve, including digital and proportional purge valves.

[0028] Figure 2A shows an embodiment of the fuel vapor pressure management apparatus 20 that is particularly suited to being mounted on the charcoal canister 18. The fuel vapor pressure management apparatus 20 includes a housing 30 that can be mounted to the body of the charcoal canister 18 by a "bayonet" style attachment 32. A seal (not shown) can be interposed between the charcoal canister 18 and the fuel vapor pressure management apparatus 20 so as to provide a fluid tight connection. The attachment 32, in combination with a snap finger 33, allows the fuel vapor pressure management apparatus 20 to be readily serviced in the field. Of course, different styles of attachments between the fuel vapor pressure management apparatus 20 and the body of the charcoal canister 18 can be substituted for the illustrated bayonet attachment 32. Examples of different attachments include a threaded attachment, and an interlocking telescopic attachment. Alternatively, the charcoal canister 18 and the housing 30 can be bonded together (e.g., using an adhesive), or the body

of the charcoal canister 18 and the housing 30 can be interconnected via an intermediate member such as a rigid pipe or a flexible hose.

[0029] The housing 30 defines an interior chamber 31 and can be an assembly of a first housing part 30a and a second housing part 30b. The first housing part 30a includes a first port 36 that provides fluid communication between the charcoal canister 18 and the interior chamber 31. The second housing part 30b includes a second port 38 that provides fluid communication, e.g., venting, between the interior chamber 31 and the ambient atmosphere. A filter (not shown) can be interposed between the second port 38 and the ambient atmosphere for reducing contaminants that could be drawn into the fuel vapor pressure management apparatus 20 during the vacuum relief 24 or during operation of the purge valve 16.

[0030] In general, it is desirable to minimize the number of housing parts to reduce the number of potential leak points, i.e., between housing pieces, which must be sealed.

[0031] An advantage of the fuel vapor pressure management apparatus 20 is its compact size. The volume occupied by the fuel vapor pressure management apparatus 20, including the interior chamber 31, is less than all other known leak detection devices, the smallest of which occupies more than 240 cubic centimeters. That is to say, the fuel vapor pressure management apparatus 20, from the first port 36 to the second port 38 and including the interior chamber 31, occupies less than 240 cubic centimeters. In particular, the fuel vapor pressure management apparatus 20 occupies a volume of less than 100 cubic centimeters. This size reduction over known leak detection devices is significant given the limited availability of space in contemporary automobiles.

[0032] A pressure operable device 40 can separate the interior chamber 31 into a first portion 31a and a second portion 31b. The first portion 31a is in fluid communication with the charcoal canister 18 through the first port 36, and the second portion 31b is in fluid communication with the ambient atmosphere through the second port 38.

[0033] The pressure operable device 40 includes a poppet 42, a seal 50, and a resilient element 60. During the signaling 22, the poppet 42 and the seal 50 cooperatively engage one another to prevent fluid communication between the first and second ports 36,38. During the vacuum relief 24, the poppet 42 and the seal 50 cooperatively engage one another to permit restricted fluid flow from the second port 38 to the first port 36. During the pressure blow-off

26, the poppet 42 and the seal 50 disengage one another to permit substantially unrestricted fluid flow from the first port 36 to the second port 38.

[0034] The pressure operable device 40, with its different arrangements of the poppet 42 and the seal 50, may be considered to constitute a bi-directional check valve. That is to say, under a first set of conditions, the pressure operable device 40 permits fluid flow along a path in one direction, and under a second set of conditions, the same pressure operable device 40 permits fluid flow along the same path in the opposite direction. The volume of fluid flow during the pressure blow-off 26 may be three to ten times as great as the volume of fluid flow during the vacuum relief 24.

[0035] The pressure operable device 40 operates without an electromechanical actuator, such as a solenoid that is used in a known leak detection device to controllably displace a fluid flow control valve. Thus, the operation of the pressure operable device 40 can be controlled exclusively by the pressure differential between the first and second ports 36,38. Preferably, all operations of the pressure operable device 40 are controlled by fluid pressure signals that act on one side, i.e., the first port 36 side, of the pressure operable device 40.

[0036] The pressure operable device 40 also operates without a diaphragm. Such a diaphragm is used in the known leak detection device to sub-partition an interior chamber and to actuate the flow control valve. Thus, the pressure operable device 40 exclusively separates, and then only intermittently, the interior chamber 31. That is to say, there are at most two portions of the interior chamber 31 that are defined by the housing 30.

[0037] The poppet 42 is preferably a low density, substantially rigid disk through which fluid flow is prevented. The poppet 42 can be flat or formed with contours, e.g., to enhance rigidity or to facilitate interaction with other components of the pressure operable device 40.

[0038] The poppet 42 can have a generally circular form that includes alternating tabs 44 and recesses 46 around the perimeter of the poppet 42. The tabs 44 can center the poppet 42 within the second housing part 30b, and guide movement of the poppet 42 along an axis A. The recesses 46 can provide a fluid flow path around the poppet 42, e.g., during the vacuum relief 24 or during the pressure blow-off 26. A plurality of alternating tabs 44 and recesses 46 are illustrated, however, there could be any number of tabs 44 or recesses 46, including none, e.g., a disk having a circular perimeter. Of course, other forms and shapes may be used for the poppet 42.

[0039] The poppet 42 can be made of any metal (e.g., aluminum), polymer (e.g., nylon), or another material that is impervious to fuel vapor, is low density, is substantially rigid, and has a smooth surface finish. The poppet 42 can be manufactured by stamping, casting, or molding. Of course, other materials and manufacturing techniques may be used for the poppet 42.

[0040] The seal 50 can have an annular form including a bead 52 and a lip 54. The bead 52 can be secured between and seal the first housing part 30a with respect to the second housing part 30b. The lip 54 can project radially inward from the bead 52 and, in its undeformed configuration, i.e., as-molded or otherwise produced, project obliquely with respect to the axis A. Thus, preferably, the lip 54 has the form of a hollow frustum. The seal 50 can be made of any material that is sufficiently elastic to permit many cycles of flexing the seal 50 between undeformed and deformed configurations.

[0041] Preferably, the seal 50 is molded from rubber or a polymer, e.g., nitriles or fluorosilicones. More preferably, the seal has a stiffness of approximately 50 durometer (Shore A), and is self-lubricating or has an anti-friction coating, e.g., polytetrafluoroethylene.

[0042] Figure 2B shows an exemplary embodiment of the seal 50, including the relative proportions of the different features. Preferably, this exemplary embodiment of the seal 50 is made of Santoprene 123-40.

[0043] The resilient element 60 biases the poppet 42 toward the seal 50. The resilient element 60 can be a coil spring that is positioned between the poppet 42 and the second housing part 30b. Preferably, such a coil spring is centered about the axis A.

[0044] Different embodiments of the resilient element 60 can include more than one coil spring, a leaf spring, or an elastic block. The different embodiments can also include various materials, e.g., metals or polymers. And the resilient element 60 can be located differently, e.g., positioned between the first housing part 30a and the poppet 42.

[0045] It is also possible to use the weight of the poppet 42, in combination with the force of gravity, to urge the poppet 42 toward the seal 50. As such, the biasing force supplied by the resilient element 60 could be reduced or eliminated.

[0046] The resilient element 60 provides a biasing force that can be calibrated to set the value of the first predetermined pressure level. The construction of the resilient element 60, in

particular the spring rate and length of the resilient member, can be provided so as to set the value of the second predetermined pressure level.

[0047] A switch 70 can perform the signaling 22. Preferably, movement of the poppet 42 along the axis A actuates the switch 70. The switch 70 can include a first contact fixed with respect to a body 72 and a movable contact 74. The body 72 can be fixed with respect to the housing 30, e.g., the first housing part 30a, and movement of the poppet 42 displaces movable contact 74 relative to the body 72, thereby closing or opening an electrical circuit in which the switch 70 is connected. In general, the switch 70 is selected so as to require a minimal actuation force, e.g., 50 grams or less, to displace the movable contact 74 relative to the body 72.

[0048] Different embodiments of the switch 70 can include magnetic proximity switches, piezoelectric contact sensors, or any other type of device capable of signaling that the poppet 42 has moved to a prescribed position or that the poppet 42 is exerting a prescribed force on the movable contact 74.

[0049] Referring now to Figure 2C, there is shown an alternate embodiment of the fuel vapor pressure management apparatus 20'. As compared to Figure 2A, the fuel vapor pressure management apparatus 20' provides an alternative second housing part 30b' and an alternate poppet 42'. Otherwise, the same reference numbers are used to identify similar parts in the two embodiments of the fuel vapor pressure management apparatus 20 and 20'.

[0050] The second housing part 30b' includes a wall 300 projecting into the chamber 31 and surrounding the axis A. The poppet 42' includes at least one corrugation 420 that also surrounds the axis A. The wall 300 and the at least one corrugation 420 are sized and arranged with respect to one another such that the corrugation 420 slidingly receives the wall 300 as the poppet 42' moves along the axis A, i.e., to provide a dashpot type structure. Preferably, the wall 300 and the at least one corrugation 420 are right-circle cylinders.

[0051] The wall 300 and the at least one corrugation 420 cooperatively define a sub-chamber 310 within the chamber 31'. Movement of the poppet 42' along the axis A causes fluid displacement between the chamber 31' and the sub-chamber 310. This fluid displacement has the effect of damping resonance of the poppet 42'. A metering aperture (not show) could be provided to define a dedicated flow channel for the displacement of fluid between the chamber 31' and the sub-chamber 310'.

[0052] As it is shown in Figure 2C, the poppet 42' can include additional corrugations that can enhance the rigidity of the poppet 42', particularly in the areas at the interfaces with the seal 50 and the resilient element 60.

[0053] The signaling 22 occurs when vacuum at the first predetermined pressure level is present at the first port 36. During the signaling 22, the poppet 42 and the seal 50 cooperatively engage one another to prevent fluid communication between the first and second ports 36,38.

[0054] The force created as a result of vacuum at the first port 36 causes the poppet 42 to be displaced toward the first housing part 30a. This displacement is opposed by elastic deformation of the seal 50. At the first predetermined pressure level, e.g., one inch of water vacuum relative to the atmospheric pressure, displacement of the poppet 42 will actuate the switch 70, thereby opening or closing an electrical circuit that can be monitored by an electronic control unit 74. As vacuum is released, i.e., the pressure at the first port 36 rises above the first predetermined pressure level, the elasticity of the seal 50 pushes the poppet 42 away from the switch 70, thereby resetting the switch 70.

[0055] During the signaling 22, there is a combination of forces that act on the poppet 42, i.e., the vacuum force at the first port 36 and the biasing force of the resilient element 60. This combination of forces moves the poppet 42 along the axis A to a position that deforms the seal 50 in a substantially symmetrical manner. This arrangement of the poppet 42 and seal 50 are schematically indicated in Figure 3A. In particular, the poppet 42 has been moved to its extreme position against the switch 70, and the lip 54 has been substantially uniformly pressed against the poppet 42 such that there is, preferably, annular contact between the lip 54 and the poppet 42.

[0056] In the course of the seal 50 being deformed during the signaling 22, the lip 54 slides along the poppet 42 and performs a cleaning function by scraping-off any debris that may be on the poppet 42.

[0057] The vacuum relief 24 occurs as the pressure at the first port 36 further decreases, i.e., the pressure decreases below the first predetermined pressure level that actuates the switch 70. At some level of vacuum that is below the first predetermined level, e.g., six inches of water vacuum relative to atmosphere, the vacuum acting on the seal 50 will deform the lip 54 so as to at least partially disengage from the poppet 42.

[0058] During the vacuum relief 24, it is believed that, at least initially, the vacuum relief 24 causes the seal 50 to deform in an asymmetrical manner. This arrangement of the poppet 42 and seal 50 are schematically indicated in Figure 3B. A weakened section of the seal 50 could facilitate propagation of the deformation. In particular, as the pressure decreases below the first predetermined pressure level, the vacuum force acting on the seal 50 will, at least initially, cause a gap between the lip 54 and the poppet 42. That is to say, a portion of the lip 54 will disengage from the poppet 42 such that there will be a break in the annular contact between the lip 54 and the poppet 42, which was established during the signaling 22. The vacuum force acting on the seal 50 will be relieved as fluid, e.g., ambient air, flows from the atmosphere, through the second port 38, through the gap between the lip 54 and the poppet 42, through the first port 36, and into the canister 18.

[0059] The fluid flow that occurs during the vacuum relief 24 is restricted by the size of the gap between the lip 54 and the poppet 42. It is believed that the size of the gap between the lip 54 and the poppet 42 is related to the level of the pressure below the first predetermined pressure level. Thus, a small gap is all that is formed to relieve pressure slightly below the first predetermined pressure level, and a larger gap is formed to relieve pressure that is significantly below the first predetermined pressure level. This resizing of the gap is performed automatically by the seal 50 in accordance with the construction of the lip 54, and is believed to eliminate pulsations due to repeatedly disengaging and reengaging the seal 50 with respect to the poppet 42. Such pulsations could arise due to the vacuum force being relieved momentarily during disengagement, but then building back up as soon as the seal 50 is reengaged with the poppet 42.

[0060] Referring now to Figure 3C, the pressure blow-off 26 occurs when there is a positive pressure above a second predetermined pressure level at the first port 36. For example, the pressure blow-off 26 can occur when the tank 12 is being refueled. During the pressure blow-off 26, the poppet 42 is displaced against the biasing force of the resilient element 60 so as to space the poppet 42 from the lip 54. That is to say, the poppet 42 will completely separate from the lip 54 so as to eliminate the annular contact between the lip 54 and the poppet 42, which was established during the signaling 22. This separation of the poppet 42 from the seal 50 enables the lip 54 to assume an undeformed configuration, i.e., it returns to its "as-originally-manufactured" configuration. The pressure at the second

predetermined pressure level will be relieved as fluid flows from the canister 18, through the first port 36, through the space between the lip 54 and the poppet 42, through the second port 38, and into the atmosphere.

[0061] The fluid flow that occurs during the pressure blow-off 26 is substantially unrestricted by the space between the poppet 42 and the lip 54. That is to say, the space between the poppet 42 and the lip 54 presents very little restriction to the fluid flow between the first and second ports 36,38.

[0062] At least four advantages are achieved in accordance with the operations performed by the fuel vapor pressure management apparatus 20. First, providing a leak detection diagnostic using vacuum monitoring during natural cooling, e.g., after the engine is turned off. Second, providing relief for vacuum below the first predetermined pressure level, and providing relief for positive pressure above the second predetermined pressure level. Third, vacuum relief provides fail-safe purging of the canister 18. And fourth, the relieving pressure 26 regulates the pressure in the fuel tank 12 during any situation in which the engine is turned off, thereby limiting the amount of positive pressure in the fuel tank 12 and allowing the cool-down vacuum effect to occur sooner.

[0063] Figure 4A shows a plot 200 of flow versus pressure for the fuel vapor pressure management apparatus 20. Generally, the plot 200 describes the overall operating characteristics, which may be viewed as including three segments and two transitions. The middle segment is characterized by the absence of fluid flow, such as occurs in a "nominal" arrangement and in the arrangement that occurs during the signaling 22. The nominal arrangement refers to the state of the fuel vapor pressure management apparatus 20 wherein the poppet 42 is at an intermediate position, e.g., it has not yet moved to its extreme position against the switch 70, but the poppet 42 is substantially uniformly pressed against the lip 54 of the seal 50.

[0064] The first transition from the middle segment occurs between the signaling 22 and the vacuum relief 24, e.g., as the pressure continues to decrease to a level less than that of the first predetermined pressure level. This first transition is shown in Figure 4A as occurring at approximately –1.5 inches water for the fuel vapor pressure management apparatus 20. It is notable that this first transition occurs rather abruptly as the lip 54 deforms asymmetrically, at least initially, so as to form the gap between the poppet 42 and the seal 50.

[0065] The left segment is characterized by negative fluid flow, i.e., in the direction from the atmosphere to the headspace, such as in the arrangement that occurs during the vacuum relief 24. It is notable that, at a first period after the beginning of the vacuum relief 24, the flow increases rapidly for relatively small decreases in pressure, and that during a subsequent second period, the flow is generally proportional to the change in pressure. It is believed that the size of the gap that is initially created by the asymmetrical deformation of the lip 54 increases during the first period, but that there is little or no change in the gap size during the second period.

[0066] The second transition from the middle segment occurs at the second predetermined pressure level. This second transition is shown in Figure 4A as occurring at slightly above zero inches water, i.e., slightly above ambient atmospheric pressure. Preferably, the second transition occurs at less than 2 inches water, and more preferably at less than 0.5 inches water.

[0067] Referring to Figure 4B, there may be some hysteresis effects associated with the second transition. For example, initially after the second predetermined pressure level is exceeded, there may be a period in which there is a rise in the pressure acting on the poppet 42 without a proportional increase in flow between the poppet 42 and the seal 50. It is believed that this hysteresis effect may occur until the contiguous engagement between the poppet 42 and seal 50 is broken. Figure 4B shows that the first predetermined pressure level is preferably at approximately -1 inch water, the first transition to the vacuum relief 24 preferably occurs at approximately -2 inches water, and the second predetermined pressure level is preferably at approximately 0.35 inches water.

[0068] Referring again to Figure 4A, the right segment is characterized by positive fluid flow, i.e., in the direction from the headspace to the atmosphere, such as in the arrangement that occurs during the pressure blow-off 26. It is notable that once flow commences at the second transition, the flow is generally proportional to the pressure.

[0069] Thus, the fuel vapor pressure management apparatus 20 provides rapid and precise control of the vacuum relief 24 to protect the integrity of the fuel system 10 from potentially damaging vacuum forces. And the fuel vapor pressure management apparatus 20 provides smooth and progressive control of the pressure blow-off 26 to protect the integrity of the fuel system 10 from potentially damaging pressure build-up, as well as to facilitate ORVR.

[0070] Figure 4C shows the plot 200 of flow versus pressure for the fuel vapor pressure management apparatus 20 as compared to a similar plot 210 for a known leak detection device. The first transition, as shown in Figure 4C, occurs at approximately −1.5 inches water for the fuel vapor pressure management apparatus 20, and at approximately −3 inches water for the known leak detection device. It is notable that this first transition occurs more abruptly in the fuel vapor pressure management apparatus 20, and occurs more gradually in the known leak detection device. With regard to the left segment, it is notable that for a given pressure, the fuel vapor pressure management apparatus 20 permits greater flow rates than the known leak detection device. Figure 4C also shows that the second transition occurs more gradually in the fuel vapor pressure management apparatus 20, and occurs more abruptly in the known leak detection device. With regard to the right segment, it is notable that the fuel vapor pressure management apparatus 20 provides flow that is more proportionate to a wider range of pressures, whereas the known leak detection device provides flow that is less proportionate to a narrower range of pressures.

[0071] It is advantageous that there is very little pressure drop through the pressure operable device 40, in general, and across the seal 50, in particular. Another advantage of the fuel vapor pressure management apparatus 20 is that, because of the poppet 42 has a large diameter (and a corresponding large surface of the face that is acted upon by the pressure in the charcoal canister 18), the range of movement by the poppet 42 can be made minimized. Preferably, the range is no more than 2.5 millimeters between the first position of the poppet 42 (e.g., at the extreme of the pressure blow-off 26) and the second position of the poppet 42 (e.g., at the extreme of the signaling 22). More preferably, the range of movement for the poppet 42 between the intermediate and first positions is no more than 2 millimeters (e.g., during OVRV) and between the intermediate and second positions is no more than 0.5 millimeters.

[0072] While the present invention has been disclosed with reference to certain preferred embodiments, numerous modifications, alterations, and changes to the described embodiments are possible without departing from the sphere and scope of the present invention, as defined in the appended claims. Accordingly, it is intended that the present invention not be limited to the described embodiments, but that it have the full scope defined by the language of the following claims, and equivalents thereof.

What is claimed is:

1. A fuel vapor pressure management apparatus comprising:

a housing defining an interior chamber, the housing including first and second ports communicating with the interior chamber; and

a pressure operable device separating the interior chamber into a first portion in fluid communication with the first port and a second portion in fluid communication with a second port, the pressure operable device including a poppet movable along an axis and a seal adapted to cooperatively engage the poppet, a first arrangement of the pressure operable device occurs when there is a first negative pressure level at the first port relative to the second port and the seal is in a first deformed configuration, a second arrangement of the pressure operable device permits a first fluid flow from the second port to the first port when the seal is in a second deformed configuration, and a third arrangement of the pressure operable device permits a second fluid flow from the first port to the second port when the seal is in an undeformed configuration.

2. The fuel vapor pressure management apparatus according to claim 1, wherein the housing comprises first and second parts, the first part defines the first port, and the second part defines the second port.

3. The fuel vapor pressure management apparatus according to claim 2, wherein the seal comprises a bead and a lip, and the bead is secured between the first and second parts of the housing.

4. The fuel vapor pressure management apparatus according to claim 1, wherein the seal comprises a bead and a lip, and the lip in the undeformed configuration projects inwardly and obliquely toward the axis.

5. The fuel vapor pressure management apparatus according to claim 1, wherein the poppet is movable along the axis between a first position, a second position, and an intermediate position between the first and second positions.

6. The fuel system according to claim 5, wherein the first and second arrangements of the pressure operable device comprise the poppet in the second position, and the third arrangement of the pressure operable device comprises the poppet in the first position.

7. The fuel vapor pressure management apparatus according to claim 5, further comprising:

a fourth arrangement of the pressure operable device that prevents fluid communication between the first and second ports, and fourth arrangement comprises the poppet in the intermediate position and the seal in the first deformed configuration.

8. The fuel vapor pressure management apparatus according to claim 7, further comprising:

a switch that signals the first arrangement of the pressure operable device and does not signal the fourth arrangement of the pressure operable device.

9. The fuel vapor pressure management apparatus according to claim 8, wherein the pressure operable device comprises a resilient element biasing the poppet toward the second position, the resilient element preloading the switch in the fourth arrangement.

10. The fuel vapor pressure management apparatus according to claim 1, further comprising:

a switch signaling the first arrangement wherein the first negative pressure level exists at the first port relative to the second port.

11. The fuel vapor pressure management apparatus according to claim 10, wherein the housing comprises first and second parts, the first part defines the first port, the second part defines the second port, and the switch is disposed within the first part of the housing.

12. The fuel vapor pressure management apparatus according to claim 11, further comprising:

a circuit board supporting the switch and being disposed in the first part of the housing.

13. The fuel vapor pressure management apparatus according to claim 12, wherein the switch comprises first contact that is generally movable with respect to the circuit board and a second contact that is substantially fixed with respect to the circuit board.

14. The fuel vapor pressure management apparatus according to claim 1, wherein the pressure operable device comprises a resilient element biasing the poppet toward the seal.

15. The fuel vapor pressure management apparatus according to claim 14, further comprising:

an adjuster calibrating a biasing force of the resilient element.

16. The fuel vapor pressure management apparatus according to claim 15, wherein the housing comprises first and second parts, the first part defines the first port, the second part defines the second port, the resilient element extends between the poppet and the adjuster, and the adjuster is disposed on the second part of the housing.

17. The fuel vapor pressure management apparatus according to claim 14, wherein the resilient element comprises a coil spring that is compressed in the third arrangement of the pressure operable device.

18. The fuel vapor pressure management apparatus according to claim 1, wherein the poppet is substantially rigid and the seal is relatively flexible with respect to the poppet.

19. The fuel vapor pressure management apparatus according to claim 1, wherein the first deformed configuration comprises a substantially symmetrical deformation of the seal, and the second deformed configuration comprises a generally asymmetrical deformation of the seal.

20. The fuel vapor pressure management apparatus according to claim 1, wherein movement of the poppet is independent of an electromechanical actuator.

21. The fuel vapor pressure management apparatus according to claim 1, wherein the pressure operable device excludes a diaphragm partitioning the interior chamber.

22. The fuel vapor pressure management apparatus according to claim 1, wherein the second fluid flow is substantially unrestricted between the first and second ports, and the first fluid flow is relatively restricted with respect to the second fluid flow.

23. The fuel vapor pressure management apparatus according to claim 1, wherein the housing and the interior chamber occupy a volume less than 240 cubic centimeters.

24. The fuel vapor pressure management apparatus according to claim 1, wherein the second arrangement of the pressure operable device occurs when a second negative pressure level is at the first port relative to the second level, and the second negative pressure level is less than the first negative pressure level.

25. The fuel vapor pressure management apparatus according to claim 1, wherein the third arrangement of the pressure operable device occurs when a positive pressure level is at the first port relative to the second port.

26. A fuel vapor pressure management apparatus comprising:

a housing defining an interior chamber, the housing and the interior chamber occupying a volume less than 240 cubic centimeters; and

a pressure operable device occupying a first space in the interior chamber, the pressure operable device performing a leak diagnostic based on a negative pressure at a first pressure level, the pressure operable device relieving negative pressure below the first pressure level, and the pressure operable device blowing-off positive pressure above a second pressure level.

27. The apparatus according to claim 26, wherein the negative pressure results from naturally occurring vacuum due to cooling fuel vapors.

28. The apparatus according to claim 26, further comprising:

a switch occupying a second space in the interior chamber, the switch cooperating with the pressure operable device to indicate the negative pressure at the first pressure level.

29. The apparatus according to claim 28, further comprising:

a printed circuit board occupying a third space in the interior chamber, the printed circuit board mechanically supporting the switch and being electrically connected to the switch.

30. A method of managing fuel vapor pressure in a fuel system, the method comprising:

locating between first and second ports a poppet and a seal cooperating with the poppet, the poppet being movable along an axis, and the seal being flexible between an undeformed configuration when disengaged from the poppet, a substantially symmetrically deformed configuration when engaged with the poppet, and a generally asymmetrically deformed configuration when engaged with the poppet;

positioning the seal in the substantially symmetrically deformed configuration so as to sense a negative pressure at a first pressure level;

positioning the seal in the generally asymmetrically deformed configuration so as to vent negative pressure below the first pressure level; and

positioning the seal in the undeformed configuration so as to vent positive pressure above a second pressure level.

31. The method according to claim 30, wherein the seal is elastically flexible between the undeformed, the substantially symmetrically deformed, and the generally asymmetrically deformed configurations.

32. The method according to claim 30, wherein the poppet is movable along the axis between a first position, a second position, and an intermediate position between the first and second positions.

33. The method according to claim 32, wherein the positioning the seal in the substantially symmetrically deformed and the generally asymmetrically deformed configurations comprises the poppet in the second position, and the positioning the seal in the undeformed configuration comprises the poppet in the first position.

34. The method according to claim 32, further comprising:

positioning the seal in the substantially symmetrically deformed configuration and positioning the poppet in the intermediate position so as to prevent fluid flow between the first and second ports.

35. The method according to claim 30, wherein the positioning the seal in the generally asymmetrically deformed configuration permits a first fluid flow along a path in a first direction so as to vent negative pressure below the first pressure level, the positioning the seal in the undeformed configuration permits a second fluid flow along the path in a second direction so as to vent positive pressure above a second pressure level, and the second direction is opposite to the first direction.

36. The method according to claim 35, wherein the second fluid flow is substantially unrestricted by the positioning the seal in the undeformed configuration, and the positioning the seal in the generally asymmetrically deformed configuration restricts the first fluid flow relative to the second fluid flow.

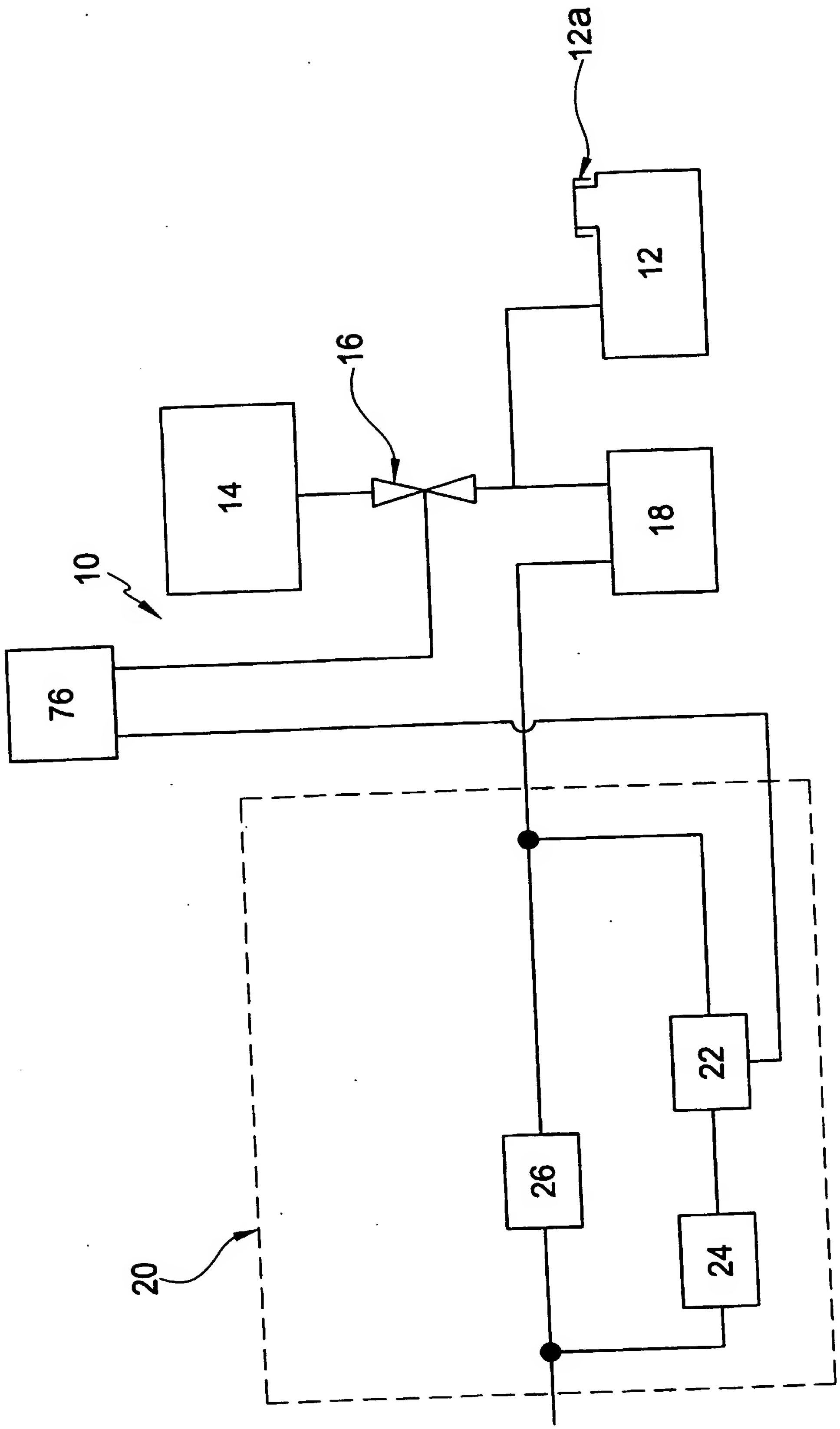


FIG.1

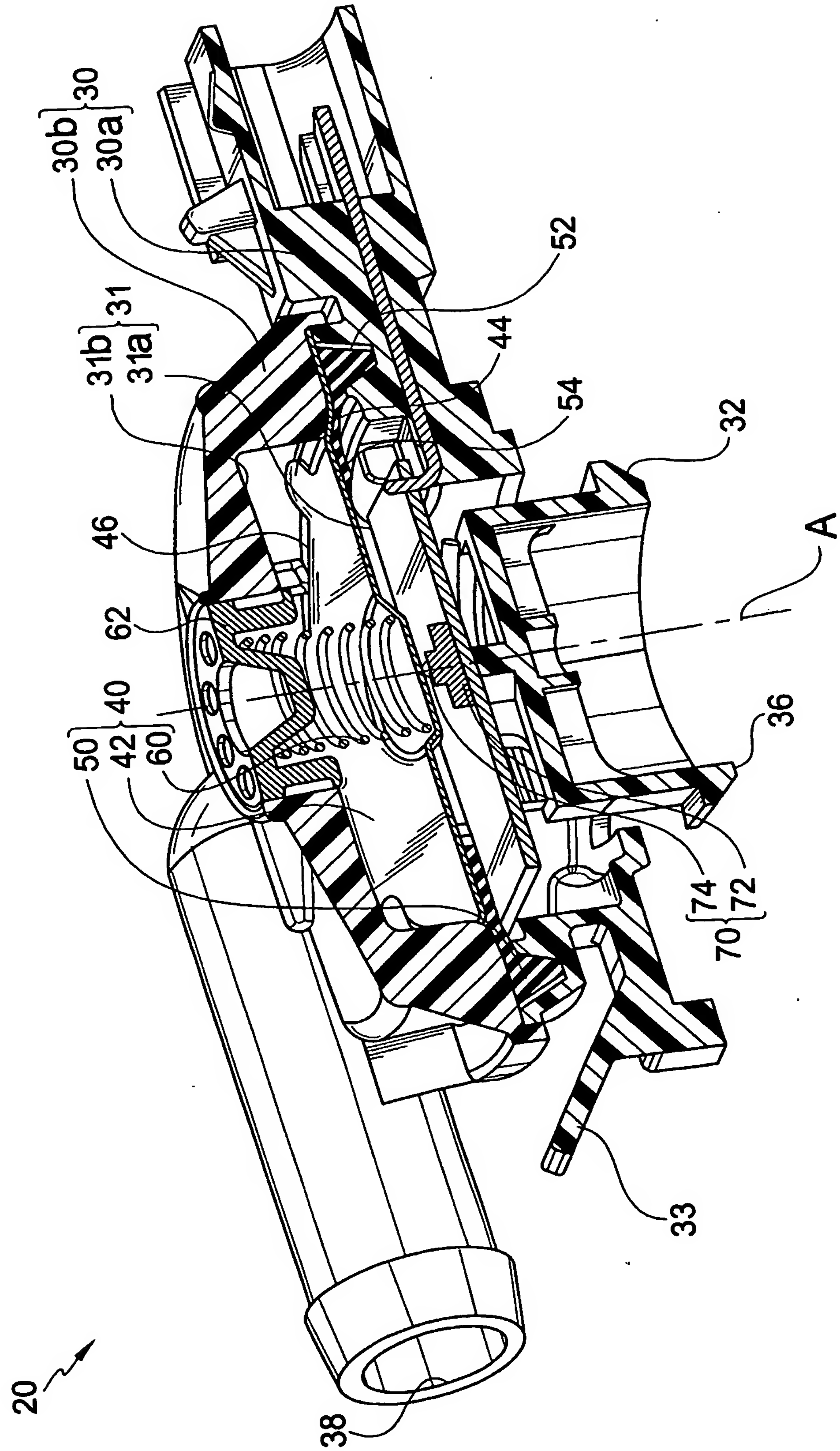

30
30a
30b
31
31a
31b
52
44
54
32
46
62
40
42
50
60
A
36
74
72
70
33
38
20

FIG.2A

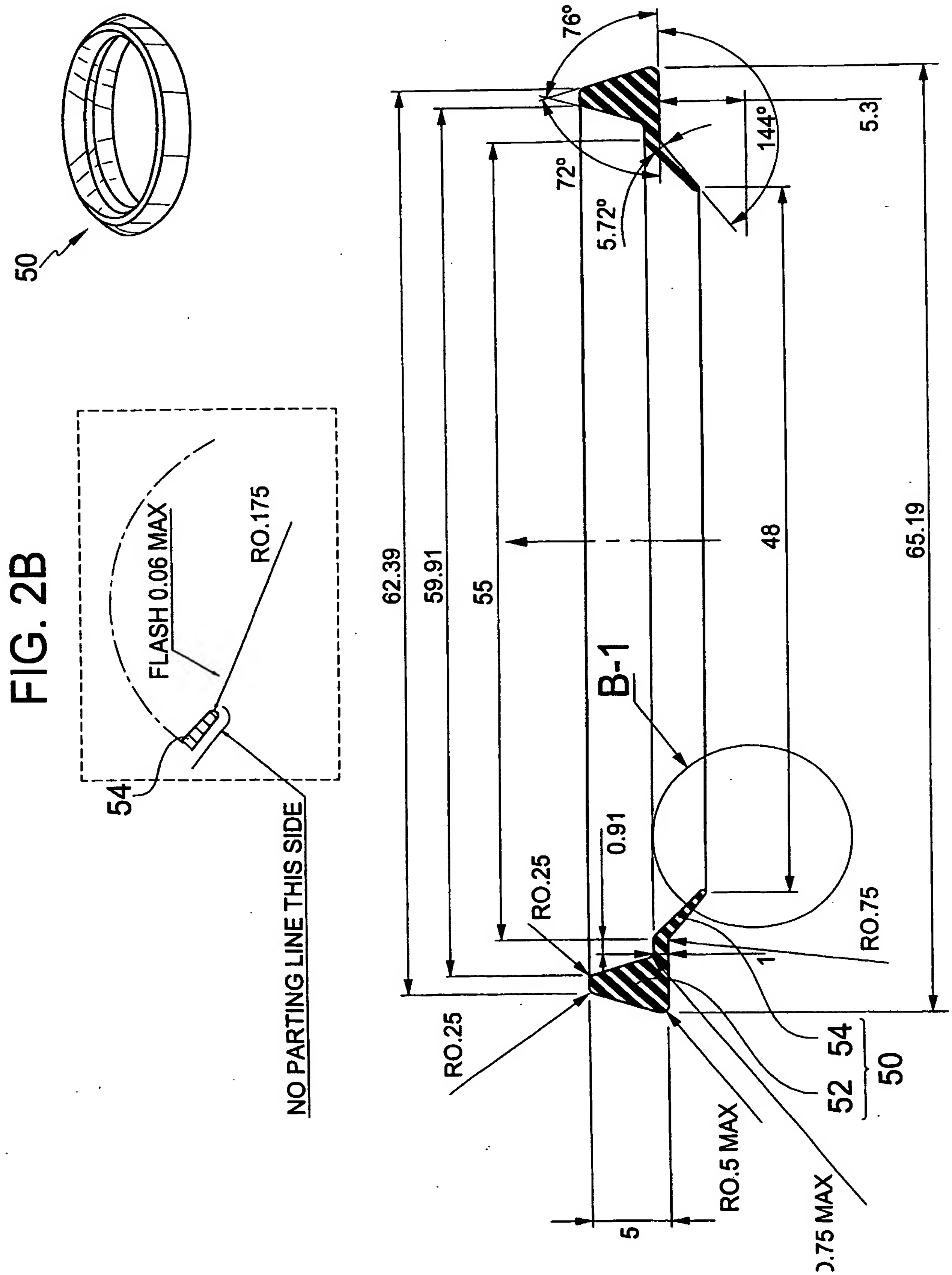

50
54
FLASH 0.06 MAX
RO.175
NO PARTING LINE THIS SIDE
76°
72°
144°
5.72°
5.3
62.39
59.91
55
48
65.19
B-1
RO.25
0.91
RO.75
1
54
52
50
RO.25
RO.5 MAX
0.75 MAX
5

FIG. 2B

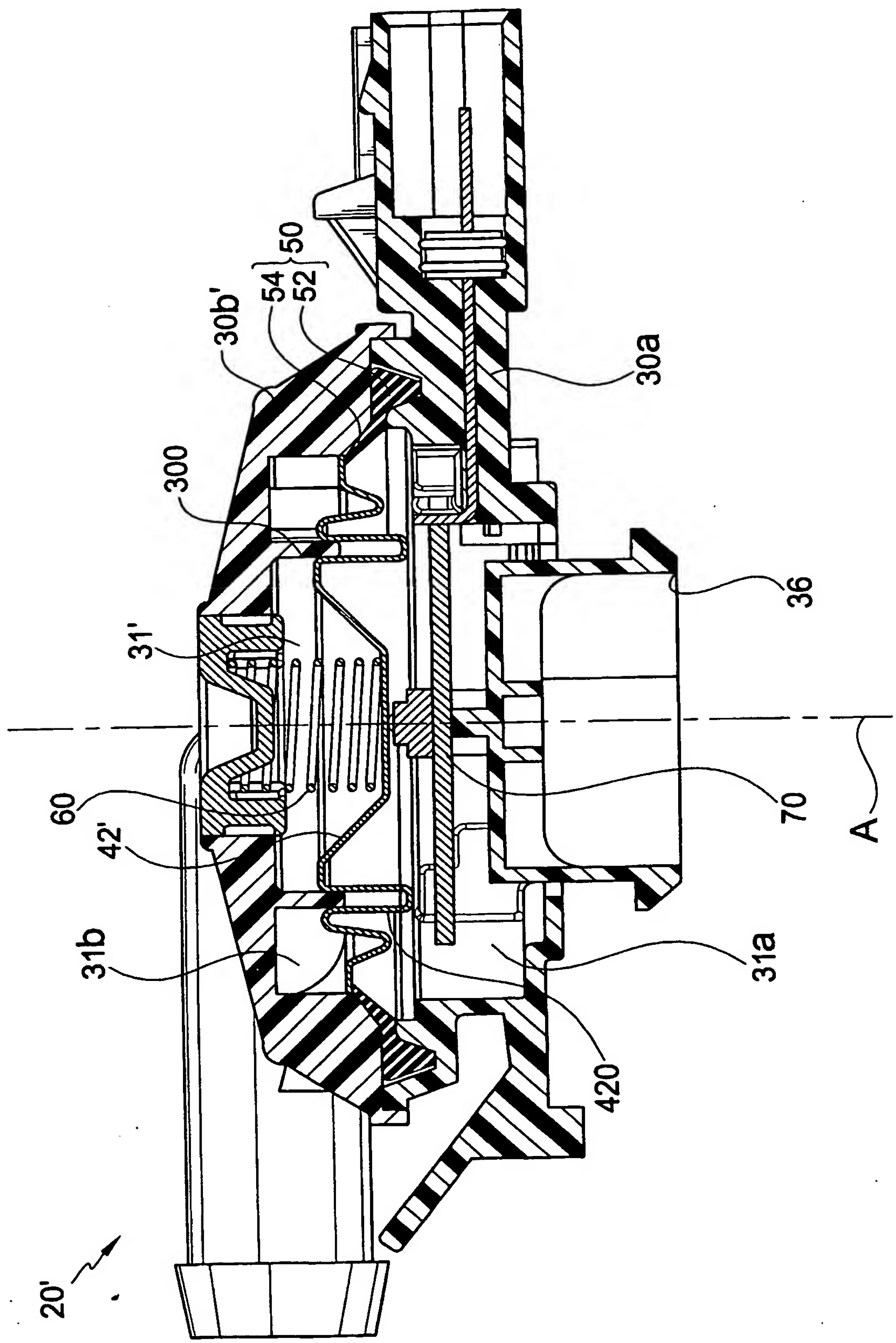


FIG.2C

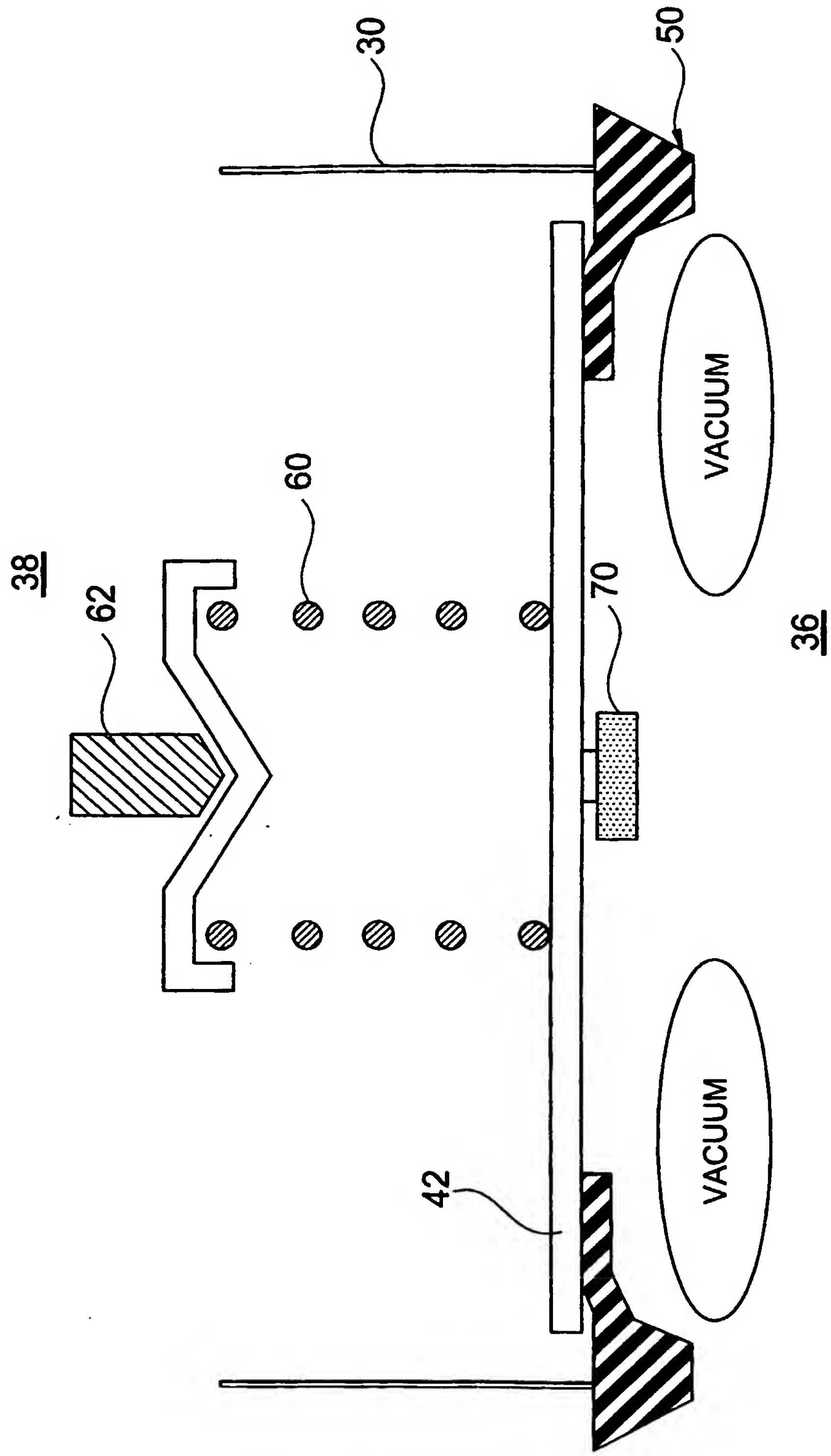


FIG.3A

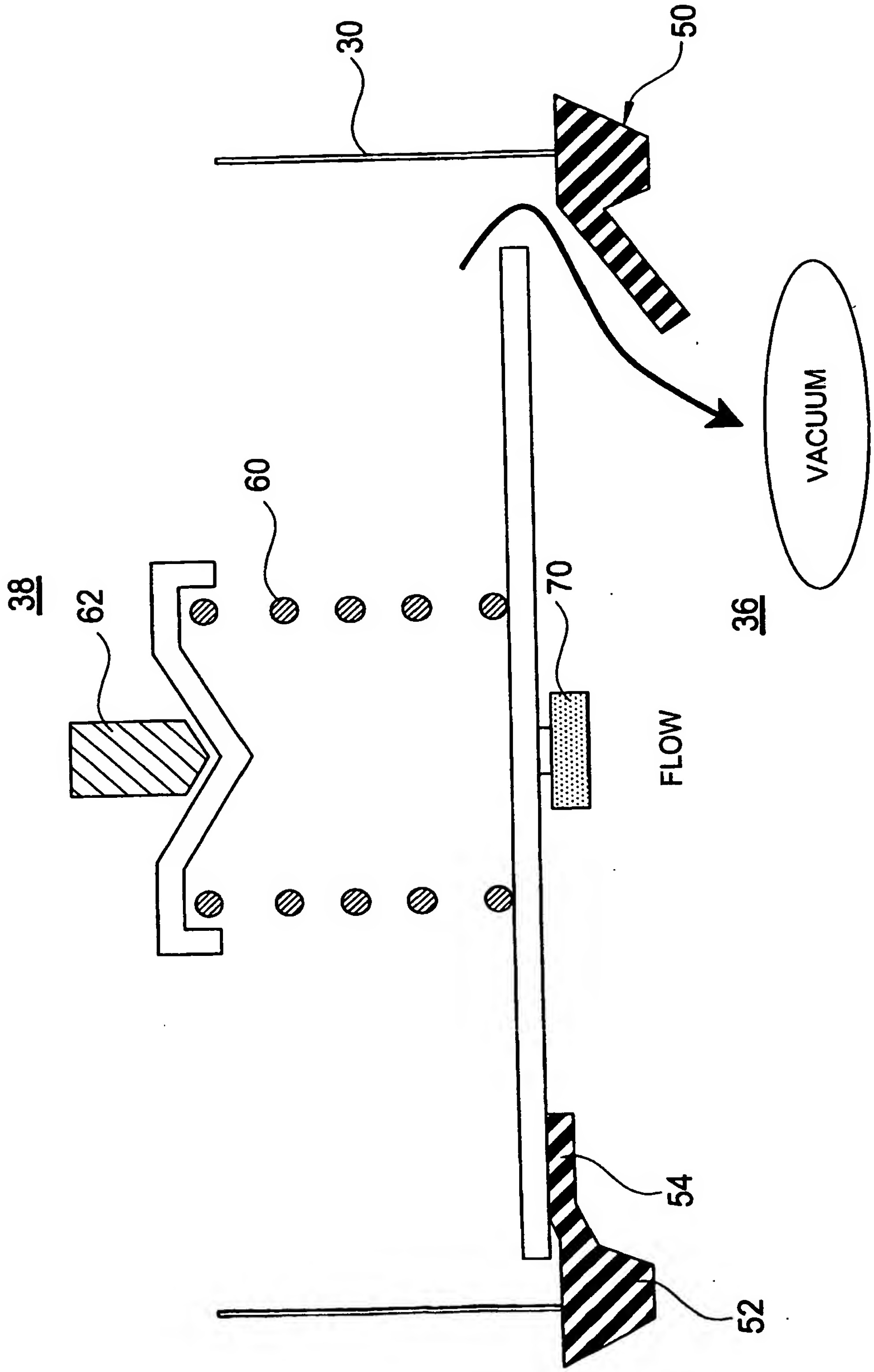


FIG.3B

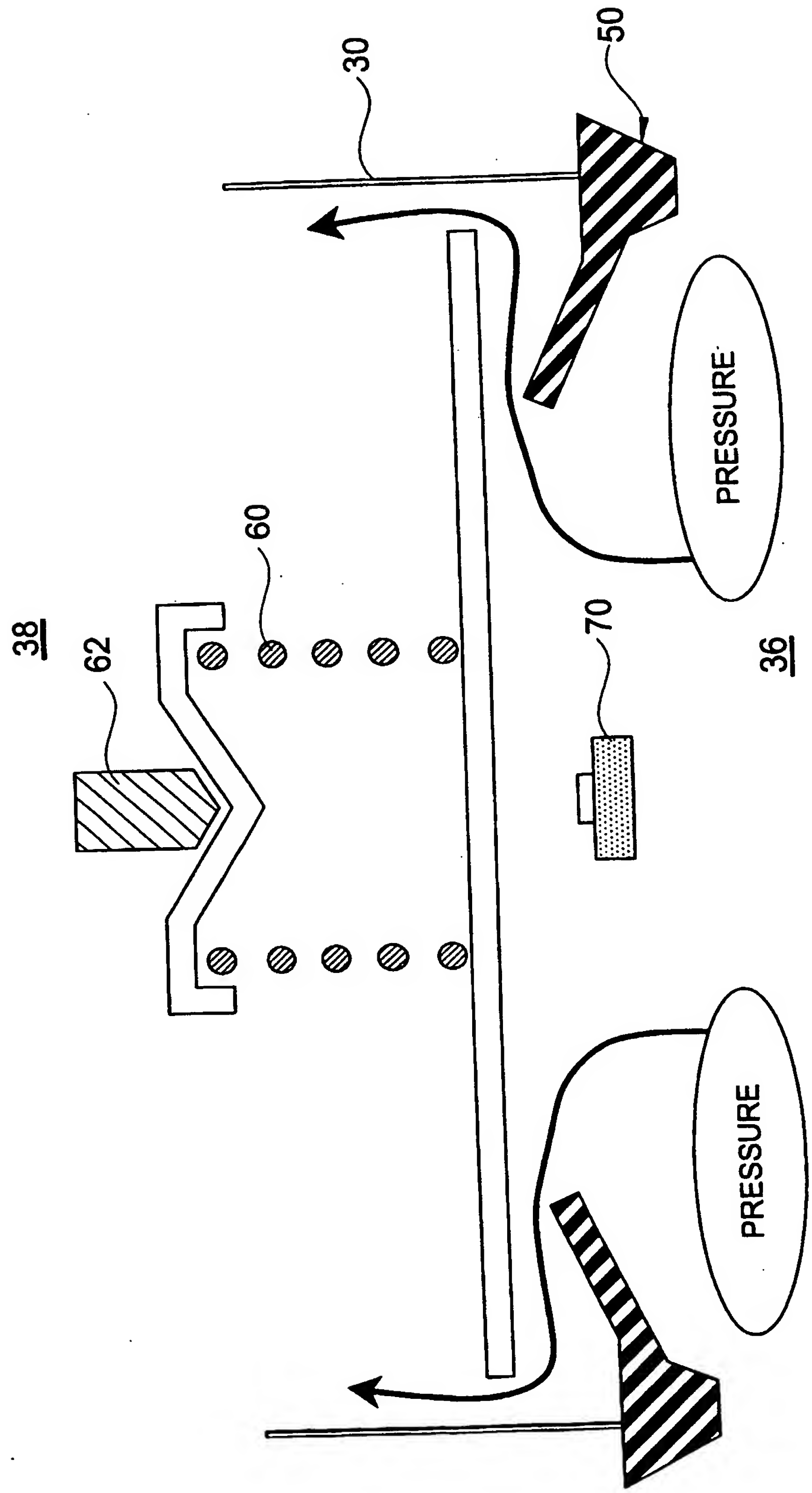
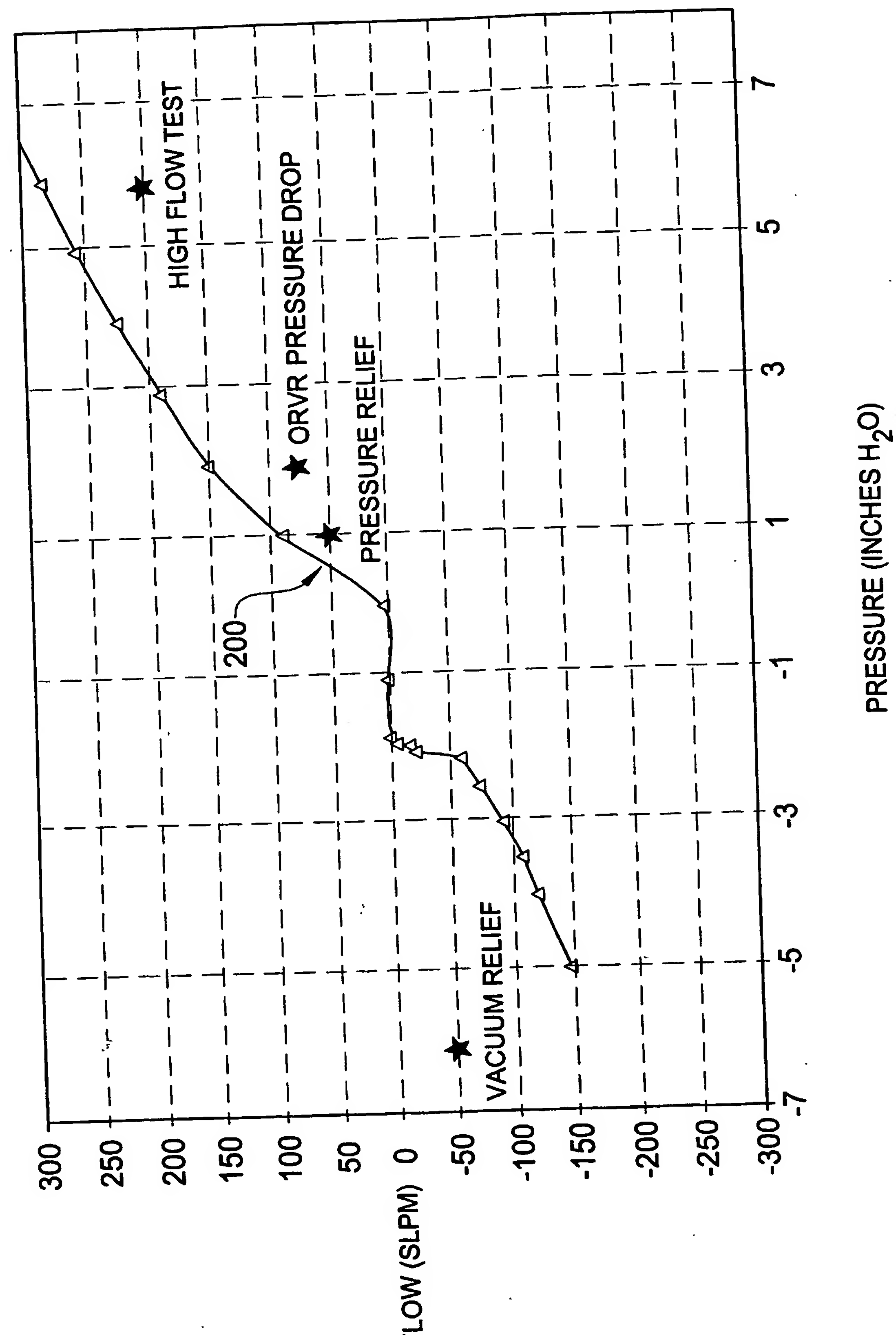
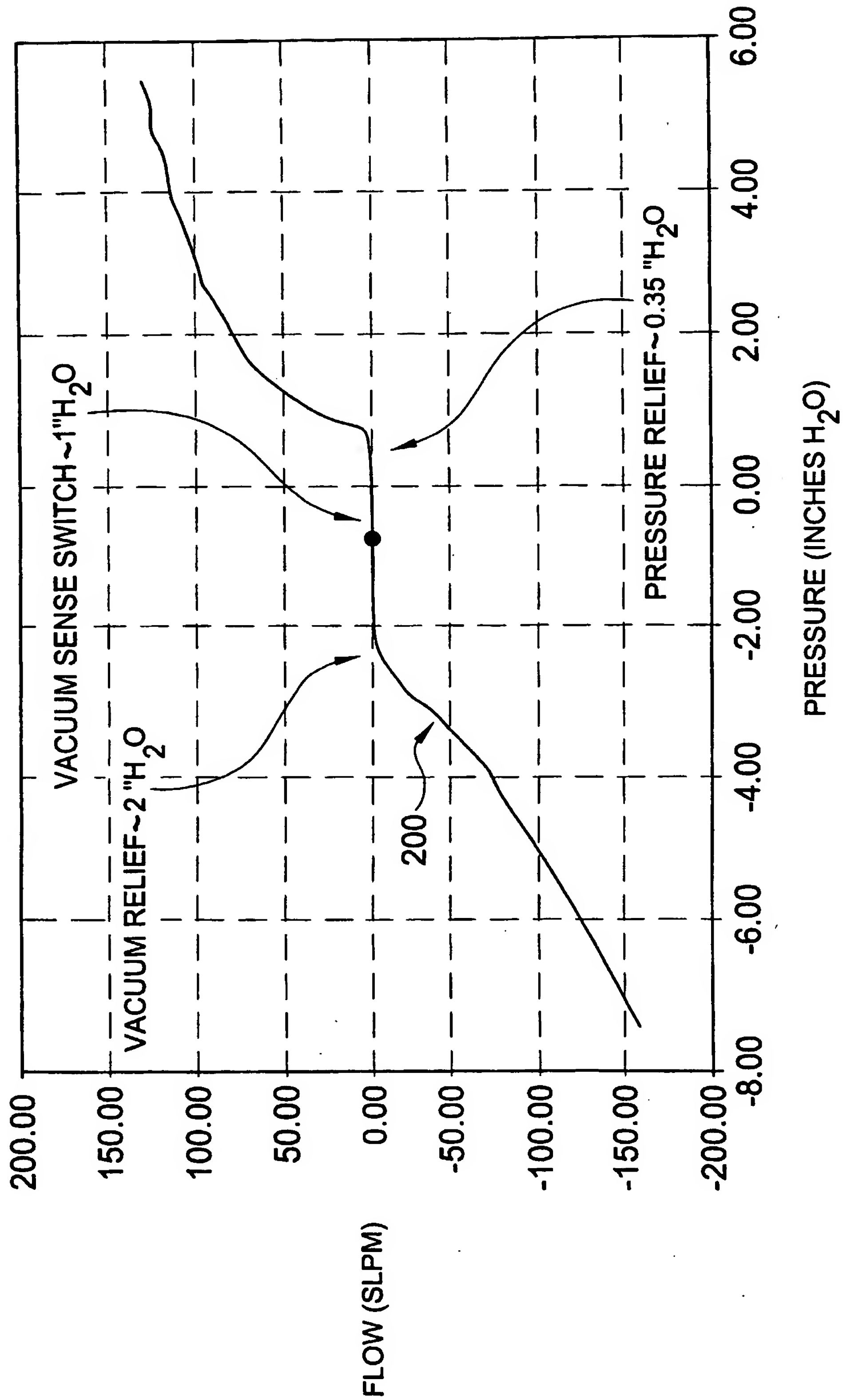


FIG.3C

FIG.4A

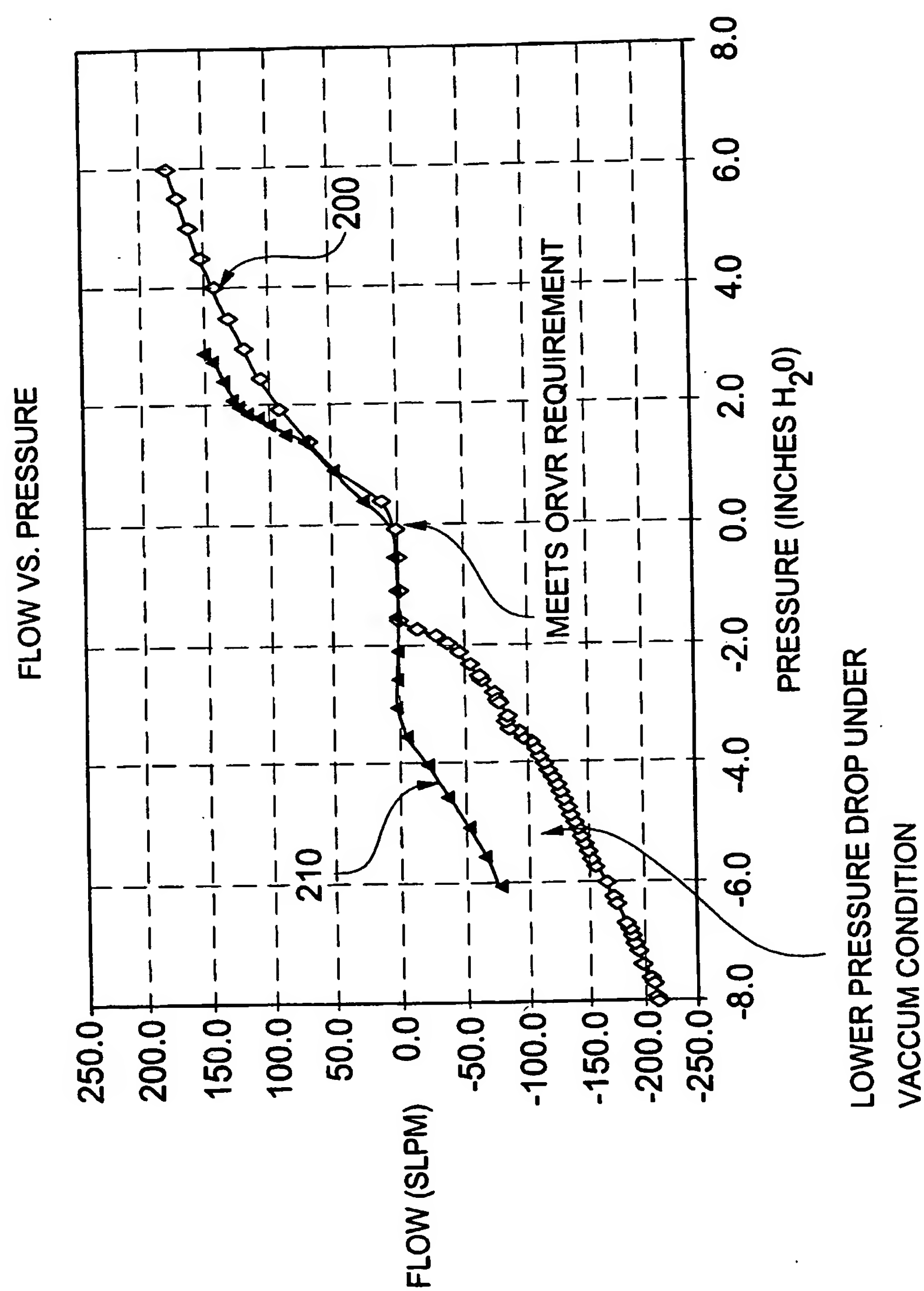

HIGH FLOW TEST
ORVR PRESSURE DROP
PRESSURE RELIEF
VACUUM RELIEF
200
300
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
:LOW (SLPM)
-7
-5
-3
-1
1
3
5
7
PRESSURE (INCHES H_2O)



VACUUM SENSE SWITCH~1"H_2O
PRESSURE RELIEF~0.35 "H_2O
VACUUM RELIEF~2 "H_2O
200
200.00
150.00
100.00
50.00
0.00
-50.00
-100.00
-150.00
-200.00
FLOW (SLPM)
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
PRESSURE (INCHES H_2O)

FIG.4B

FIG.4C


FLOW VS. PRESSURE
FLOW (SLPM)
250.0
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
-250.0
-8.0
-6.0
-4.0
-2.0
0.0
2.0
4.0
6.0
8.0
PRESSURE (INCHES H_20)
200
210
MEETS ORVR REQUIREMENT
LOWER PRESSURE DROP UNDER
VACCUM CONDITION

INTERNATIONAL SEARCH REPORT

International Application No
PCT/CA 02/00902

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 F02M25/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 F02M F16K B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3 741 232 A (SOBERSKI GEORGE A) 26 June 1973 (1973-06-26)	1,2,5, 14,17, 18,20, 22-25
Y	figures	10-13, 15,16
A	column 2, line 37 -column 5, line 18	3,4,6-9, 19,21, 26-36

X	WO 01 38716 A (SIEMENS CANADA LTD) 31 May 2001 (2001-05-31)	26-29
Y	abstract; figures	10-13, 15,16
A	page 2, last paragraph -page 5, paragraph 3	1-9,14, 17-25, 30-36

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 October 2002	23/10/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Döring, M

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 524 662 A (BENJEY ROBERT P ET AL) 11 June 1996 (1996-06-11) abstract; figures column 3, line 18 - line 44 column 5, line 1 -column 6, line 17	1,26,30

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/CA 02/00902

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
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			WO	0138716	A1	31-05-2001
			EP	1234110	A1	28-08-2002
			US	2002096149	A1	25-07-2002
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			US	2002096152	A1	25-07-2002
			US	6328021	B1	11-12-2001
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			US	6453942	B1	24-09-2002
US 5524662	A	11-06-1996	US	5215110	A	01-06-1993
			US	5054508	A	08-10-1991